

This listing of claims will replace all prior versions, and listings, of claims in the application:

Claim 1 (canceled)

1 Claim 2 (previously presented): An orthogonal frequency
2 division multiplexing (OFDM) communication device, comprising:
3 an OFDM receiver for receiving an OFDM signal
4 containing a multitone synchronization signal;
5 a synchronization interval sampler coupled to said
6 receiver;
7 an initial time and frequency offset estimator
8 connected to said sampler and said receiver; and
9 a frequency offset estimate refinement unit connected
10 to said receiver, said sampler and said estimator,
11 wherein a reference multitone synchronization signal
12 is used by said estimator and said refinement device in
13 calculating a time offset and a frequency offset of said
14 multitone synchronization signal, said receiver utilizing said
15 time offset and said frequency offset to synchronize with said
16 received OFDM signal, and
17 wherein said initial time and frequency offset
18 estimator comprises:
19 a plurality of smoothed time-domain correlation
20 estimators for outputting a series of time offset estimate and
21 correlation estimate pairs, each pair related to a frequency
22 offset estimate; and
23 a selector for selecting a selected time offset
24 estimate and a selected initial frequency offset based in part

25 upon the selection of the frequency offset estimate and time
26 offset estimate that corresponds with the largest value of
27 correlation estimate.

1 Claim 3 (original): The system of claim 2, wherein the initial
2 time and frequency offset estimator uses a coarse frequency
3 discretization using F candidate frequency offsets.

1 Claim 4 (original): The system of claim 2, wherein said
2 reference multitone synchronization signal has a length of T ,
3 and wherein said frequency offset estimate refinement device
4 comprises:

5 a T -length interval extractor for extracting a T -
6 length sample of the output of said sampler;

7 a numerical oscillator for generating a complex
8 exponential of a candidate frequency offset;

9 a multiplier for multiplying said T -length sample with
10 said complex exponential to obtain a frequency shifted
11 received signal;

12 a correlator for correlating said frequency shifted
13 received signal with said reference multitone
14 synchronization signal and producing a correlation output;
15 and

16 a numerical optimizer for receiving said correlation
17 output and outputting a new frequency offset candidate.

1 Claim 5 (previously presented): The system of claim 4, wherein
2 said new frequency offset candidate and a time offset associated

3 with said new frequency offset candidate are used by said
4 receiver if said new frequency offset candidate is a candidate
5 that yields a maximum correlation output.

Claim 6 (canceled)

1 Claim 7 (previously presented): The system of claim 2, wherein
2 each of said smoothed time domain correlation estimators
3 comprises:

4 a time domain correlator;

5 a smoothing filter connected to said time domain
6 correlator and receiving an output from said time domain
7 correlator; and

8 a maximum detector connected to and receiving an
9 output from said smoothing filter for detecting a signal energy
10 maxima representing a time estimate at which the energy of said
11 reference multitone synchronization signal is at a maximum.

1 Claim 8 (canceled)

1 Claim 9 (currently amended): ~~The method of claim 8, further~~
2 ~~comprising~~

3 A method of synchronizing an orthogonal frequency division
4 multiplexing (OFDM) receiver with a received OFDM signal
5 comprising a multitone synchronization signal, comprising the
6 steps of:

7 obtaining a coarse time offset estimate of said
8 received signal;

9 sampling said received signal in a selected time
10 interval to derive samples of said multitone synchronization
11 signal;
12 analyzing said samples with respect to a reference
13 multitone synchronization signal to obtain, for each sample
14 analyzed, a time offset, a frequency offset, and a signal
15 energy;
16 selecting a one of said analyzed samples with the
17 greatest signal energy to yield a selected time offset estimate
18 and a selected frequency offset estimate for use by said
19 receiver in synchronizing with said received OFDM signal; and
20 passing using said selected time offset estimate and
21 said selected frequency offset estimate to synchronize said
22 receiver for use by said receiver in synchronizing with said
23 received OFDM signal.

1 Claim 10 (currently amended): A method of carrying out OFDM
2 communications comprising:
3 receiving an OFDM signal including within it a
4 multitone synchronization signal;
5 locating said synchronization signal within said OFDM
6 signal;
7 determining a time offset value of said
8 synchronization signal;
9 determining an initial frequency offset value of said
10 synchronization signal; and
11 recursively refining said frequency offset estimate to
12 yield a selected pair of time and frequency offset values to be
13 used by said OFDM receiver ; and

14 using said selected pair of time and frequency offset
15 values to synchronize receiver operations with said received
16 OFDM signal.

1 Claim 11 (currently amended): ~~The method of claim 10,~~ A method
2 of carrying out OFDM communications comprising:
3 receiving an OFDM signal including within it a
4 multitone synchronization signal;
5 locating said synchronization signal within said OFDM
6 signal;
7 determining a time offset value of said
8 synchronization signal;
9 determining an initial frequency offset value of said
10 synchronization signal;
11 recursively refining said frequency offset estimate to
12 yield a selected pair of time and frequency offset values to be
13 used by said OFDM receiver; and
14 wherein said initial time offset value and said initial
15 frequency offset value are determined by obtaining a correlation
16 with a stored reference value of said synchronization signal.

1 Claim 12 (original): The method of claim 11, wherein said
2 correlation is performed seeking a maximum received
3 synchronization signal energy level.

Claim 13-14 (canceled)

1 Claim 15 (previously presented): An orthogonal frequency
2 division multiplexing (OFDM) communication device, comprising:
3 means for receiving an OFDM signal containing a
4 multitone synchronization signal;
5 means, coupled to said receiving means, for sampling a
6 synchronization interval of said OFDM signal;
7 means, connected to said sampling means and said
8 receiving means, for obtaining an initial time estimate and an
9 initial frequency offset estimate of said OFDM signal;
10 means, connected to said receiving means, said
11 sampling means and said estimating means, for obtaining a
12 frequency offset estimate refinement;
13 storage means, connected to said estimating means and
14 said refinement means, for storing a reference multitone
15 synchronization signal for use by said estimating means and said
16 refinement means in calculating a time offset and a frequency
17 offset of said multitone synchronization signal, said receiving
18 means utilizing said time offset and said frequency offset to
19 synchronize with said received OFDM signal;
20 a plurality of means for obtaining smoothed time-
21 domain (TDC) correlation estimates, said smoothed TDC estimate
22 means outputting a series of time offset estimate and
23 correlation estimate pairs, each pair related to a frequency
24 offset estimate; and
25 means for selecting a selected time offset estimate
26 and a selected initial frequency offset based in part upon the
27 selection of the frequency offset estimate and time offset
28 estimate that corresponds with the largest value of correlation
29 estimate.

1 Claim 16 (original): The system of claim 15, wherein each of
2 said smoothed TDC estimate means comprises:

3 a time domain correlator;

4 a smoothing filter connected to said time domain
5 correlator and receiving an output from said time domain
6 correlator; and

7 a maximum detector connected to and receiving an
8 output from said smoothing filter for detecting a signal energy
9 maxima representing a time estimate at which the energy of said
10 reference multitone synchronization signal is at a maximum.

1 Claim 17 (original): The system of claim 16, wherein the
2 estimating means uses a coarse frequency discretization using F
3 candidate frequency offsets.

1 Claim 18 (original): The system of claim 15, wherein said
2 reference multitone synchronization signal has a length of T ,
3 and wherein said refinement means comprises:

4 a T -length interval extractor for extracting a T -
5 length sample of the output of said sampler;

6 a numerical oscillator for generating a complex
7 exponential of a candidate frequency offset;

8 a multiplier for multiplying said T -length sample with
9 said complex exponential to obtain a frequency shifted received
10 signal;

11 a correlator for correlating said frequency shifted
12 received signal with said reference multitone synchronization
13 signal and producing a correlation output; and

14 a numerical optimizer for receiving said correlation
15 output and outputting a new frequency offset candidate.

1 Claim 19 (original): The system of claim 18, wherein said new
2 frequency offset candidate and a time offset associated with
3 said new frequency offset candidate are used by said receiving
4 means if said new frequency offset candidate is a candidate that
5 yields a maximum correlation output.

Claims 20 and 21 (canceled)

1 Claim 22 (currently amended): ~~The device of claim 21, further~~
2 ~~comprising~~ A device for synchronizing an orthogonal frequency
3 division multiplexing (OFDM) receiver with a received OFDM
4 signal comprising a multitone synchronization signal,
5 comprising:

6 means for obtaining a coarse time offset estimate of
7 said received signal;

8 means for sampling said received signal in a selected
9 time interval to derive samples of said multitone
10 synchronization signal;

11 means for analyzing said samples with respect to a
12 reference multitone synchronization signal to obtain, for each
13 sample analyzed, a time offset, a frequency offset, and a signal
14 energy;

15 means for selecting one of said analyzed samples with the
16 greatest signal energy to yield a selected time offset estimate
17 and a selected frequency offset estimate, wherein said selected
18 time offset estimate and said selected frequency offset estimate

19 are used by said receiver in synchronizing with said received
20 OFDM signal; and

21 means for passing said selected time offset estimate and
22 said selected frequency offset estimate to said receiver for use
23 by said receiver in synchronizing with said received OFDM
24 signal.

1 Claim 23 (currently amended): A device for carrying out OFDM
2 communications comprising:

3 means for receiving an OFDM signal including within it
4 a multitone synchronization signal;

5 means for locating said synchronization signal within
6 said OFDM signal;

7 means for determining a time offset value of said
8 synchronization signal;

9 means for determining an initial frequency offset
10 value of said synchronization signal; and

11 means for recursively refining said frequency offset
12 estimate to yield a selected pair of time and frequency offset
13 values to be used by said OFDM receiver; and

14 means for passing said selected time offset estimate
15 and said selected frequency offset estimate to a receiver
16 circuit for use by said receiver circuit in synchronizing with
17 said received OFDM signal.

1 Claim 24 (currently amended): ~~The device of claim 23,~~ A device
2 for carrying out OFDM communications comprising:

3 means for receiving an OFDM signal including within it
4 a multitone synchronization signal;

5 means for locating said synchronization signal within
6 said OFDM signal;

7 means for determining a time offset value of said
8 synchronization signal;

9 means for determining an initial frequency offset
10 value of said synchronization signal; and

11 means for recursively refining said frequency offset estimate to
12 yield a selected pair of time and frequency offset values to be
13 used by said OFDM receiver; and

14 wherein said initial time offset value and said initial
15 frequency offset value are determined by obtaining a correlation
16 with a stored reference value of said synchronization signal.

1 Claim 25 (original): The device of claim 24, wherein said
2 correlation is performed seeking a maximum received
3 synchronization signal energy level.

Claim 26-28 (canceled)

1 Claim 29 (previously presented): An OFDM signal processor
2 comprising:

3 an OFDM receiver for receiving an OFDM signal
4 containing a multitone synchronization signal;

5 a synchronization interval sampler connected to said
6 input and said receiver;

7 an initial time and frequency offset estimator
8 connected to said sampler and said receiver; and

9 a frequency offset estimate refinement device
10 connected to said receiver, said sampler and said estimator,
11 wherein a reference multitone synchronization
12 signal is used by said estimator and said refinement device in
13 calculating a time offset and a frequency offset of said
14 multitone synchronization signal, said receiver utilizing said
15 time offset and said frequency offset to synchronize with said
16 received OFDM signal, and

17 wherein said initial time and frequency offset
18 estimator comprises:

19 a plurality of smoothed time-domain
20 correlation estimators for outputting a series of time offset
21 estimate and correlation estimate pairs, each pair related to a
22 frequency offset estimate; and

23 a selector for selecting a selected time
24 offset estimate and a selected initial frequency offset based in
25 part upon the selection of the frequency offset estimate and
26 time offset estimate that corresponds with the largest value of
27 correlation estimate.

1 Claim 30 (original): The processor of claim 29, wherein each of
2 said smoothed time domain correlation estimators comprises:

3 a time domain correlator;

4 a smoothing filter connected to said time domain
5 correlator and receiving an output from said time domain
6 correlator; and

7 a maximum detector connected to and receiving an
8 output from said smoothing filter for detecting a signal energy
9 maxima representing a time estimate at which the energy of said
10 reference multitone synchronization signal is at a maximum.

1 Claim 31 (original): The processor of claim 29, wherein the
2 initial time and frequency offset estimator uses a coarse
3 frequency discretization using F candidate frequency offsets.

1 Claim 32 (original): The processor of claim 29, wherein said
2 reference multitone synchronization signal has a length of T ,
3 and wherein said frequency offset estimate refinement device
4 comprises:

5 a T -length interval extractor for extracting a T -
6 length sample of the output of said sampler;

7 a numerical oscillator for generating a complex
8 exponential of a candidate frequency offset;

9 a multiplier for multiplying said T -length sample with
10 said complex exponential to obtain a frequency shifted received
11 signal;

12 a correlator for correlating said frequency shifted
13 received signal with said reference multitone synchronization
14 signal and producing a correlation output; and

15 a numerical optimizer for receiving said correlation
16 output and outputting a new frequency offset candidate.

1 Claim 33 (original): The processor of claim 32, wherein said
2 new frequency offset candidate and a time offset associated with

3 said new frequency offset candidate are used by said receiver if
4 said new frequency offset candidate is a candidate that yields a
5 maximum correlation output.

1 Claim 34 (original): The processor of claim 32, wherein said
2 initial time and frequency offset estimator comprises:

3 a first Fast Fourier Transformer for obtaining a
4 transform of said received signal;

5 an second Fast Fourier Transformer device for
6 obtaining a transform of said reference multitone
7 synchronization signal;

8 a frequency domain correlation estimator for receiving
9 said received signal transform and said reference signal
10 transform and outputting an initial frequency offset estimate;
11 and

12 a time domain correlation estimator for receiving said
13 received signal transform and said reference signal transform
14 and said initial frequency offset estimate and outputting a time
15 offset estimate.

1 Claim 35 (currently amended): An OFDM transmitter comprising:

2 means for transmitting an OFDM signal comprising a
3 first time interval and a second time interval, each of the
4 first and second time intervals including at least one OFDM
5 symbol transmission time period, the first and second time
6 intervals recurring on a periodic basis;

7 means for transmitting data ~~at one or more data on a~~
8 plurality frequencies during said first time interval; and

9 means for transmitting, during said second time
10 interval, a plurality of synchronization ~~tone~~ tones in parallel
11 on different non-adjacent ~~, at one or more synchronization~~
12 frequencies, ~~for~~ said second time interval being a predetermined
13 time period, the frequencies of said synchronization tones in
14 said second time interval ~~tone~~ being distinct from said data
15 frequencies used to transmit data in the first time interval,
16 the first time interval immediately preceding the second time
17 interval.

1 Claim 36 (currently amended): A method for transmitting an OFDM
2 signal comprising the steps of:

3 transmitting an OFDM signal ~~comprising~~ during a first
4 time interval, and a second time interval; the first time
5 interval including at least one OFDM symbol transmission time
6 period, ~~, means for~~ said step of transmitting data during the
7 first time interval including transmitting data on a plurality
8 at one or more of data frequencies during said first time
9 interval; and

10 transmitting an OFDM signal during a second time
11 interval which includes at least one OFDM tone, said first and
12 second time intervals being consecutive time intervals,

13 ~~means for~~ transmitting, during said second time interval,
14 including transmitting a plurality of a synchronization tones
15 ~~tone,~~ at one or more a plurality of non-adjacent synchronization
16 frequencies, for a predetermined time period, the frequencies of
17 said synchronization ~~tone~~ tones being distinct from said data
18 frequencies used in the first time interval.

1 Claim 37 (new): The method of claim 35,

2 wherein the first and second time intervals are single OFDM
3 symbol transmission time periods; and

4 wherein frequencies used for synchronization
5 tones in a symbol transmission time period are not used in any
6 immediately consecutive symbol transmission time period for
7 synchronization tones.

1 Claim 38 (new): The method of claim 36,

2 wherein the first and second time intervals are single OFDM
3 symbol transmission time periods; and

4 wherein at least three frequencies are used for
5 synchronization tones during each symbol transmission time
6 period.